New HDPE Resins Offer Enhancements for New Packaging Films

Steve Imfeld, Tom Schwab, Lindsay Corcoran, Ryan Breese

SPE FLEXPACKCON

October 18th, 2017

Agenda

- **Improved WVTR performance may allow further optimization of packaging in existing markets**
  - Cereal, cookie, and cracker packaging
- **Other property changes (optics) combined with improved barrier may yield new package designs**
  - Clear and/or tough films with WVTR
  - Barrier lamination for metalized film replacement

WVTR = Water Vapor Transmission Rate

Traditional Cereal, Cookie, & Cracker Packaging Market

- **The shelf life for cereal, cookies, and crackers typically depends on the WVTR of the package**
  - Lower WVTR indicates better barrier
  - Typically use HDPE to provide WVTR performance

- **Development of PE nucleation led to further barrier improvement in some HDPE by modifying crystal orientation**

- **Package also requires adequate Machine Direction (MD) Tear to limit bag from ripping during initial opening**

Alathon MMW-HDPE Moisture Barrier Film Resins

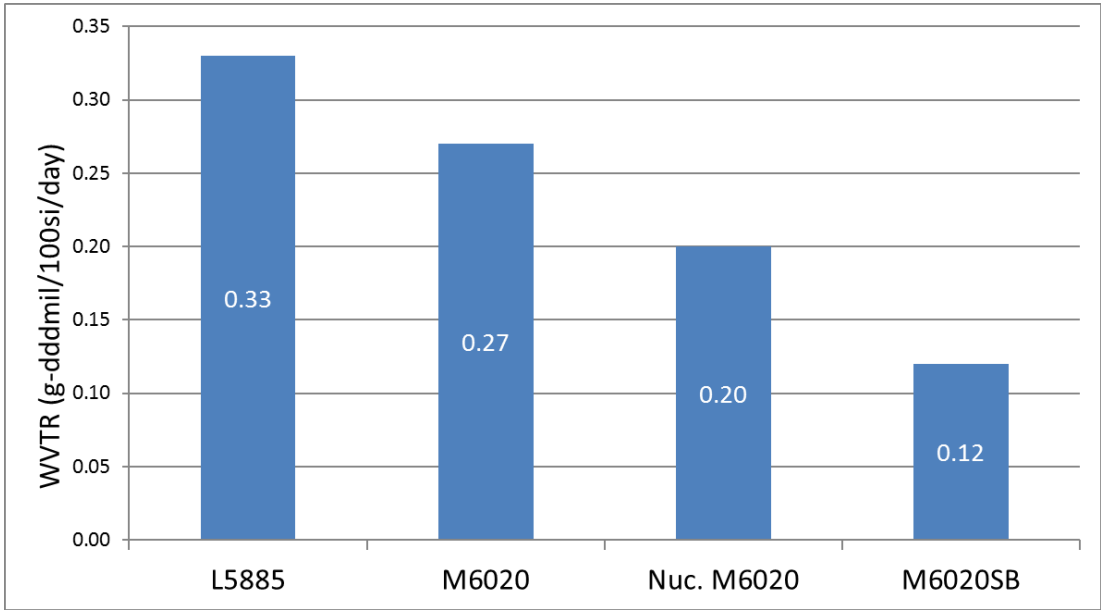
Improved WVTR ↑

Grade	Melt Index (g/10 min.)	Density (g/cc)	Typical Applications
M6020SB	2.0	0.959	High Barrier – Nucleated, improved clarity
M6020	2.0	0.959	Premium WVTR
M6210	0.95	0.958	Cereal liner, slug wrap
L5885	0.85	0.958	Cereal liner, slug wrap
L5485	0.85	0.954	Poultry packaging, frozen food
M5410	1.1	0.954	General purpose – toughness

Increasing Toughness →

Development of *Alathon* M6020SB – Nucleated WVTR HDPE

- Melt index = 2.0 g/10 min.; Density = 0.960 g/cc
- Provides significantly improved WVTR to M6020 (non-nucleated) or M6020 nucleated with a concentrate
- Maintains same processability as M6020
- Can run in any layer (skin or core) without melt fracture or dusting



M6020SB has enhanced nucleation to give significant improvement in WVTR performance

Normalized WVTR in g-mil/100 si/day for 1.25 mil monolayer blown film.

Comparison of M6020 and M6020SB as Barrier Layer

- **Produced 3-layer co-ex films**
- **Layer distribution = 15-70-15**
  - 15% skin layer using NA960000 as placeholder for sealant layer
  - 70% core using L5885 as bulk HDPE layer
  - **15% skin using M6020 or M6020SB as barrier skin layer**
- **Film Gauge = 2.0 mil**

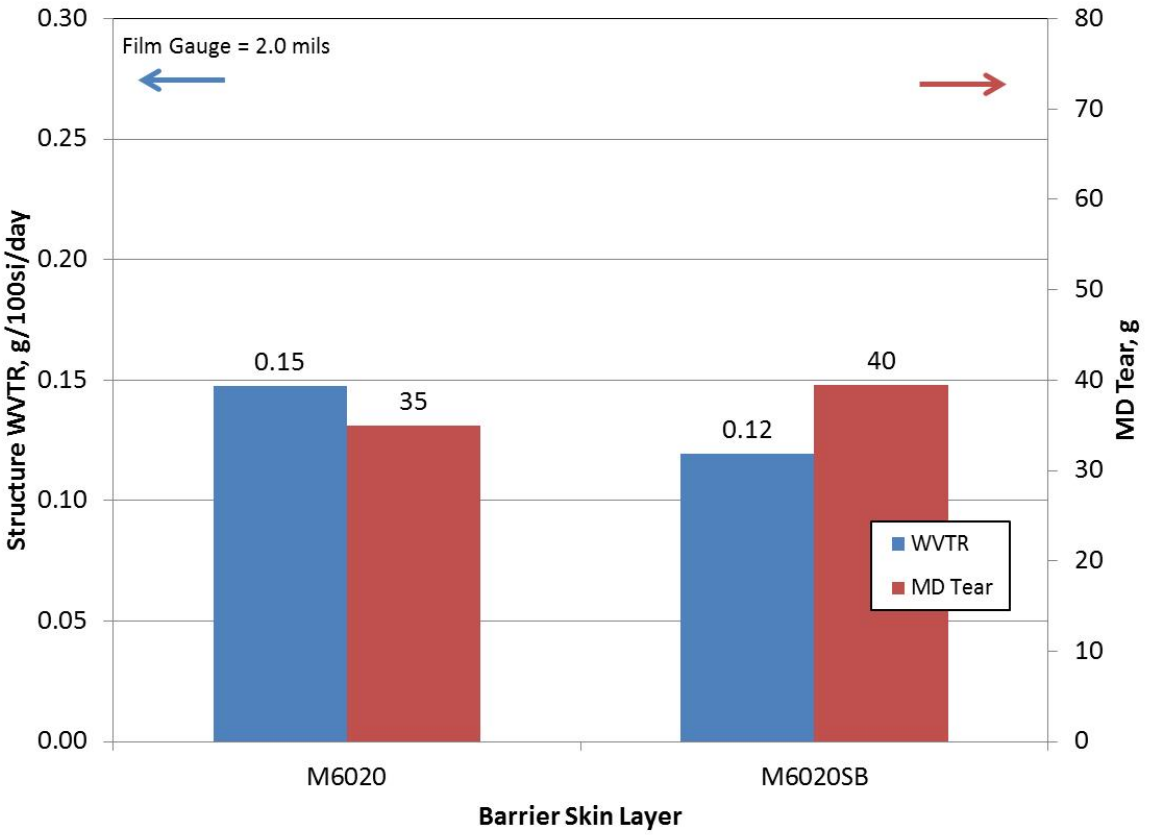
Product	Material Type	Melt Index	Density
NA960000	LDPE	1.0	0.920
L5885	HDPE	0.85	0.958
M6020	HDPE	2.0	0.960
M6020SB	Nucleated HDPE	2.0	0.960

Melt Index in g/10 min.
Density in g/cc.

Die Gap = 50 mil
Die Size = 6 inch

Blow-up Ratio = 2.5:1
Production Rate = 150 lbs/hr

Comparison of M6020 and M6020SB as Barrier Layer



- As expected, structure WVTR improves with use of M6020SB as skin layer
- Comparable MD Tear with either barrier skin layer
- Modulus and haze are also similar for both films (data not shown)
- Improved WVTR may allow structure optimization

M6020SB gives significant improvement to WVTR in co-ex structures

2.0 mil, 15-70-15 NA960000-L5885-(Barrier Skin) layer distribution

Potential New Film Markets Using M6020SB
Clear, tough films with WVTR

- **Use of LLDPE in core layer of co-ex film in place of HDPE changes optics, MD Tear, modulus, and WVTR of resulting film**

- **Layer distribution = 15-70-15**
  - 15% skin layer using NA960000 as placeholder for sealant layer
  - **70% core using LLDPE (and LLDPE-HDPE blends)**
  - 15% skin using M6020SB as barrier skin layer

- **Film Gauge = 2.0 mil**

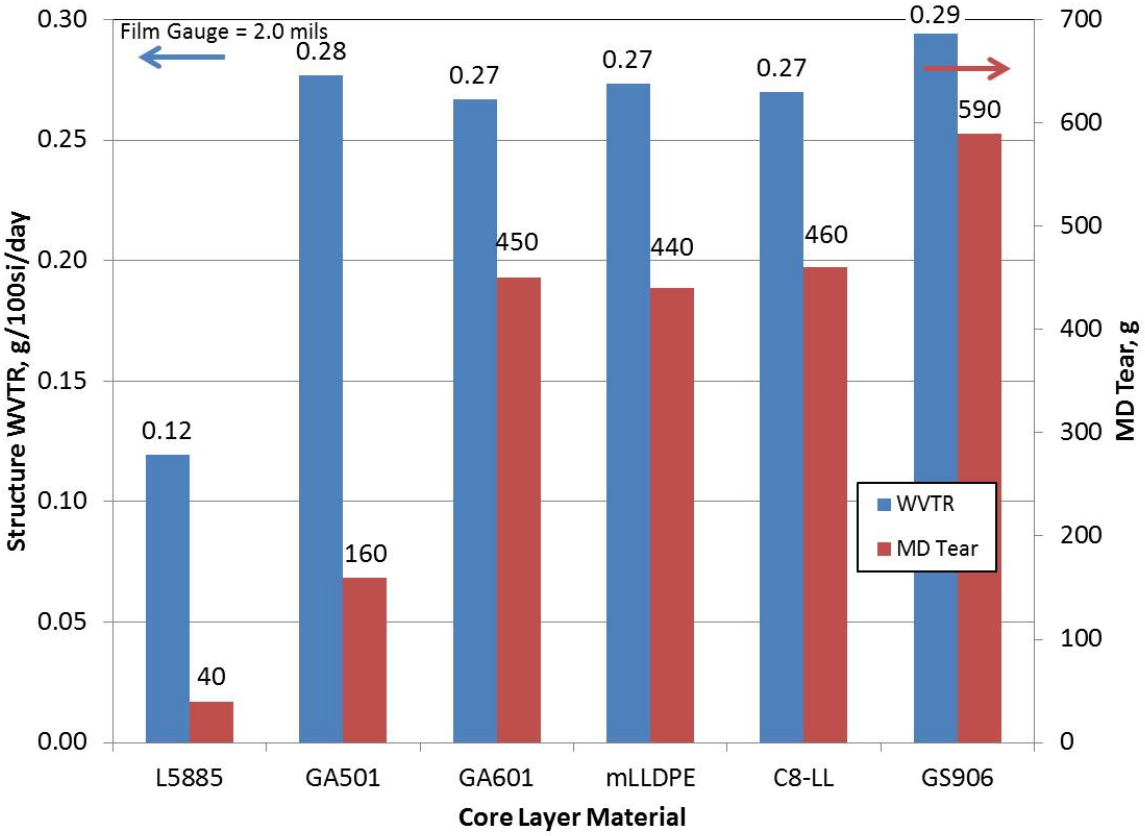
Product	Material Type	Melt Index	Density
NA960000	LDPE	1.0	0.920
GA501020	Butene-LLDPE	1.0	0.918
GA601030	Hexene-LLDPE	1.0	0.918
mLLDPE	mLLDPE	1.0	0.918
C8-LL	Octene-LLDPE	1.0	0.920
GS906061	Super-C6 LLDPE	0.6	0.916
L5885	HDPE	0.85	0.958
M6020SB	Nucleated HDPE	2.0	0.960

Melt Index in g/10 min.
Density in g/cc.

Die Gap = 50 mil
Die Size = 6 inch

Blow-up Ratio = 2.5:1
Production Rate = 150 lbs/hr

Effects of Core Layer Material Choice on WVTR Films
Core Layer is 100% of component

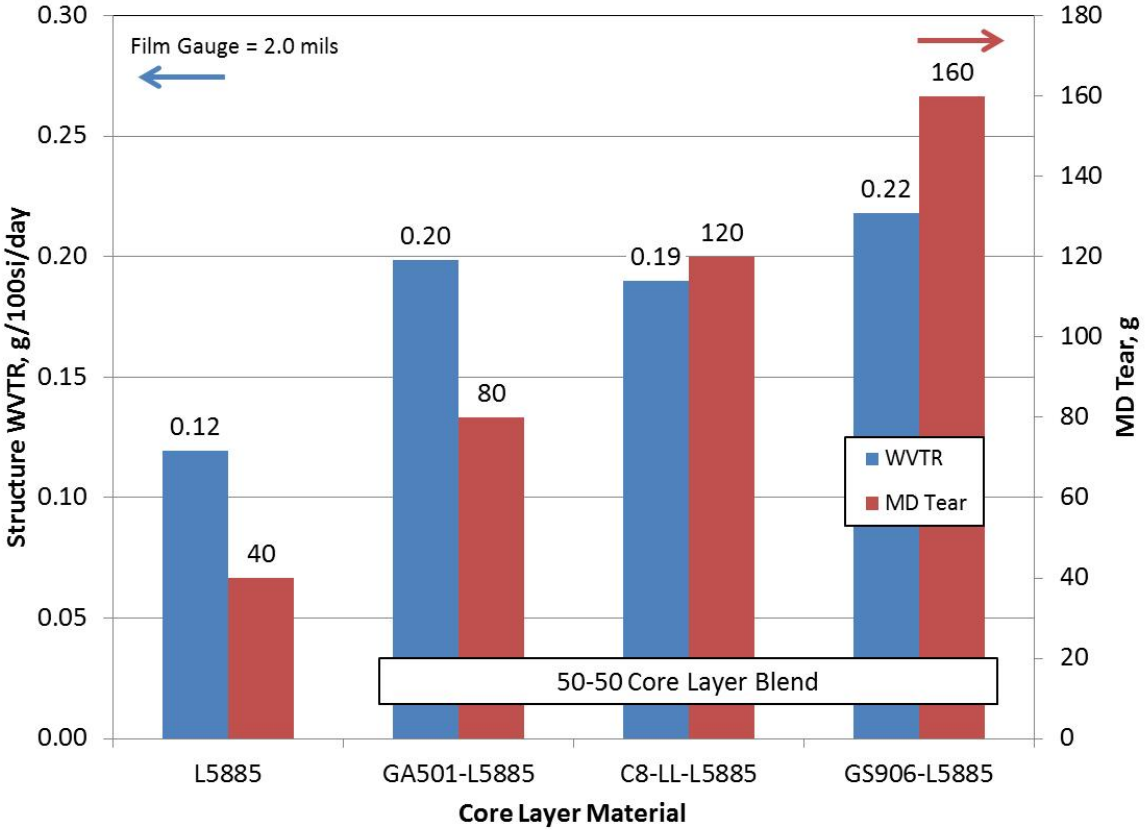


- As expected, overall WVTR increased for LLDPE cores
- Use of LLDPE as core layer significantly improved MD Tear
- GS906 increased MD Tear by ~30% over GA601, mLLDPE, and C8-LL
- Haze decreased from ~30 to 15-17 with LLDPE core (not shown)

LLDPE core layer significantly increases MD Tear and deceases haze

2.0 mil, 15-70-15 NA960000-(Core Layer)-M6020SB layer distribution
WVTR for 2.0-mil 100% LLDPE = ~0.6 g/100 si/day

Effects of Core Layer Material Choice on WVTR Films
Core Layer blends were 50-50



- As expected, overall WVTR and MD Tear decreased with addition of HDPE to core vs. 100% LLDPE core
- While MD Tear decreased for core blends, values were significantly higher than film than 100% L5885 core
- Haze for blended core was in low 20's vs. ~30 for L5885 (not shown)

Core blend ratios and/or layer distribution tweaks may give optimization

2.0 mil, 15-70-15 NA960000-(Core Layer)-M6020SB layer distribution
WVTR for 2.0-mil 100% LLDPE = ~0.6 g/100 si/day

Clear, Tough Films with WVTR Summary

- **Alternate core layer resin choices affect film properties**
- **From previous slides, for 2-mil, 15-70-15 layer distribution films**

Core Layer	100% HDPE	100% LLDPE	50-50 HDPE-LLDPE
WVTR	0.12 – 0.13	0.27 – 0.29	0.20 – 0.22
MD Tear	40 – 50	150 – 600	75 – 160
Haze	30 – 32	15 – 17	20 – 23
MD Modulus	110 – 120	40 – 50	70 – 80

- **Addition of LLDPE to core layer with M6020SB barrier skin leads to:**
  - Balancing WVTR to improve mechanical properties
  - Increased MD Tear
  - Lower haze
  - Lower MD Modulus
- **LLDPE type affects overall change in MD Tear**

2.0 mil, 15-70-15 NA960000-(Core Layer)-M6020SB layer distribution
WVTR for 2.0-mil 100% LLDPE = ~0.6 g/100 si/day
WVTR in g/100si/day. MD Tear in g. Haze in %. MD Modulus in kpsi.

Potential New Film Markets Using M6020SB
Metalized Film replacement for pouches via HDPE Barrier Lamination

- Historically, packaging requiring excellent barrier used foil or metalized film
- Consumer packaged good companies may want to show their product via windows in the package
- Use of M6020SB in film structures may provide suitable product shelf life for over-engineered packages while giving good optics

HDPE Barrier Lamination Structures

Current Metalized Structure
Reverse-printed PET/oPP Film
LDPE Laminating Layer/Adhesive
Metalized PET/oPP Film
LDPE Laminating Layer/Adhesive
PE Sealant Film

HDPE Barrier Lamination Structure
Reverse-printed PET/oPP Film
LDPE Laminating Layer
HDPE Laminating Film

- **HDPE Laminating Film uses blown film made with M6020SB with excellent WVTR**
  - Replaces metalized film, laminating/adhesive, and sealant layers
- **Potential Advantages**
  - Lower costs and improved operational efficiency
  - Food packaging differentiation – windows
  - Yield advantage to metalized PET

HDPE Barrier Lamination Samples

- **Produced ABA co-ex blown films**
  - Skin layers (A) were GS906061 (super-hexene LLDPE)
    - Primary functions are toughness and sealant layer
  - Core layer (B) was M6020SB to provide WVTR
  - Layer distribution = 15-70-15
  - Gauge = 1.8 mil and 2.7 mil

- **Produced extrusion lamination films on coating line**
  - Substrate = 48-gauge PET
  - Laminated ABA co-ex film to PET with 0.5-mil LDPE
  - For upcoming charts:

    “2.8 mil Lam” = 48-gauge PET / 0.5-mil LDPE / 1.8-mil 15-70-15 LLDPE-HDPE-LLDPE

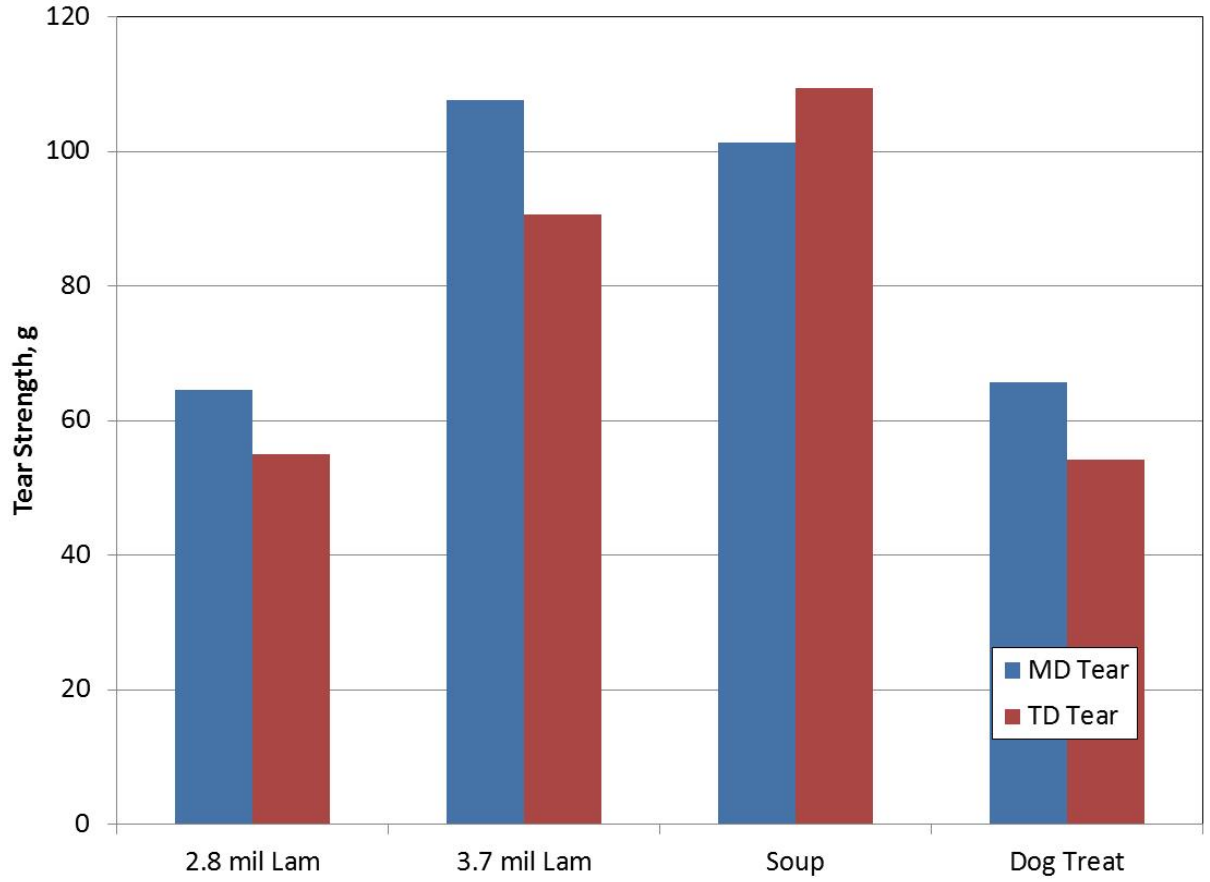
    “3.7 mil Lam” = 48-gauge PET / 0.5-mil LDPE / 2.7-mil 15-70-15 LLDPE-HDPE-LLDPE

Blown Film Line Conditions: 6-inch die, 60-mil die gap, 3.0:1 BUR
Extrusion Coating Line Conditions: 7-inch air gap, 615^{o}F melt temperature, 250 fpm
PET substrate coated with Michelman Michem® Flex Barrier 3510 Oxygen Barrier Technology

HDPE Barrier Lamination Comparison Testing

- **Purchased dry soup mix and dog treats packaged in metalized film structures**
- **Analytical testing found films were 3-ply with:**
  - Reverse printed PET primary substrate
  - Metalized PET film layer
  - PE-based sealant layer
- **Total film gauge = 4.4 mil (soup) and 3.7 mil (dog treats)**
- **Test samples cut from packages for film testing**
  - Toughness – Tear
  - Optics
  - WVTR and OTR barrier
  - Food aging

HDPE Barrier Lamination Comparison Testing
Tear



Similar tear for soup package at 19% gauge reduction.
Similar tear for dog treat package at 24% gauge reduction;
70% (63%) increase in MD (TD) Tear at same gauge.

HDPE Barrier Lamination Comparison Testing
Optics

	Soup	Dog Treat
2.8 mil Lam (Haze = 19)		
3.7 mil Lam (Haze = 24)		
Current Package (Haze not tested opaque structures)		

Barrier Lamination structures may allow product to be seen (if desired)

HDPE Barrier Lamination Comparison Testing
WVTR / OTR

Sample	WVTR	OTR
2.8 mil Lam	0.074	0.32
3.7 mil Lam	0.053	0.35
Soup (4.4 mil)	0.172	0.10
Dog Treat (3.7 mil)	0.032	0.08

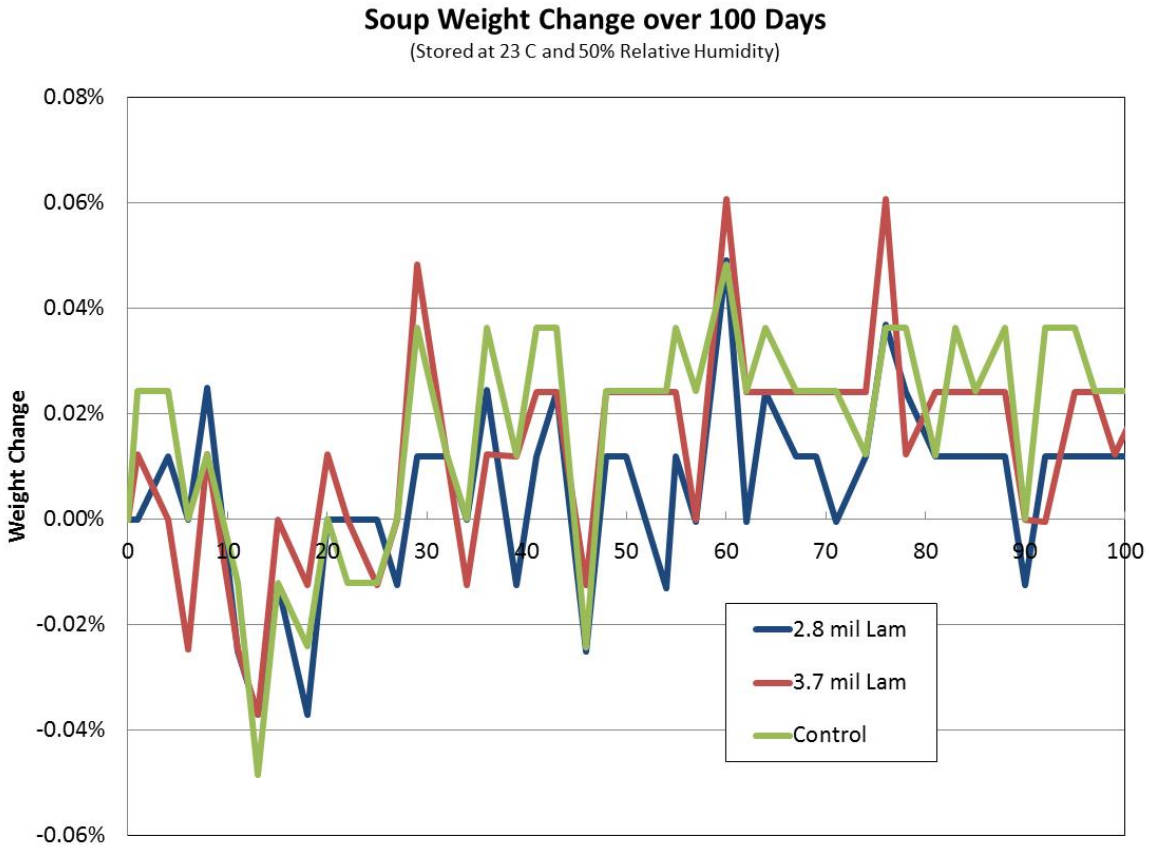
- **Soup: 2-3x improvement in WVTR at thinner gauge**
- **Lower OTR for barrier lamination samples may be possible through film structure design (EVOH)**

WVTR shown in g/100si/day tested at 37.8C, 100% RH.
OTR shown in cc/100si/day tested at 23C, 0% RH.

HDPE Barrier Lamination Comparison Testing
Food Aging

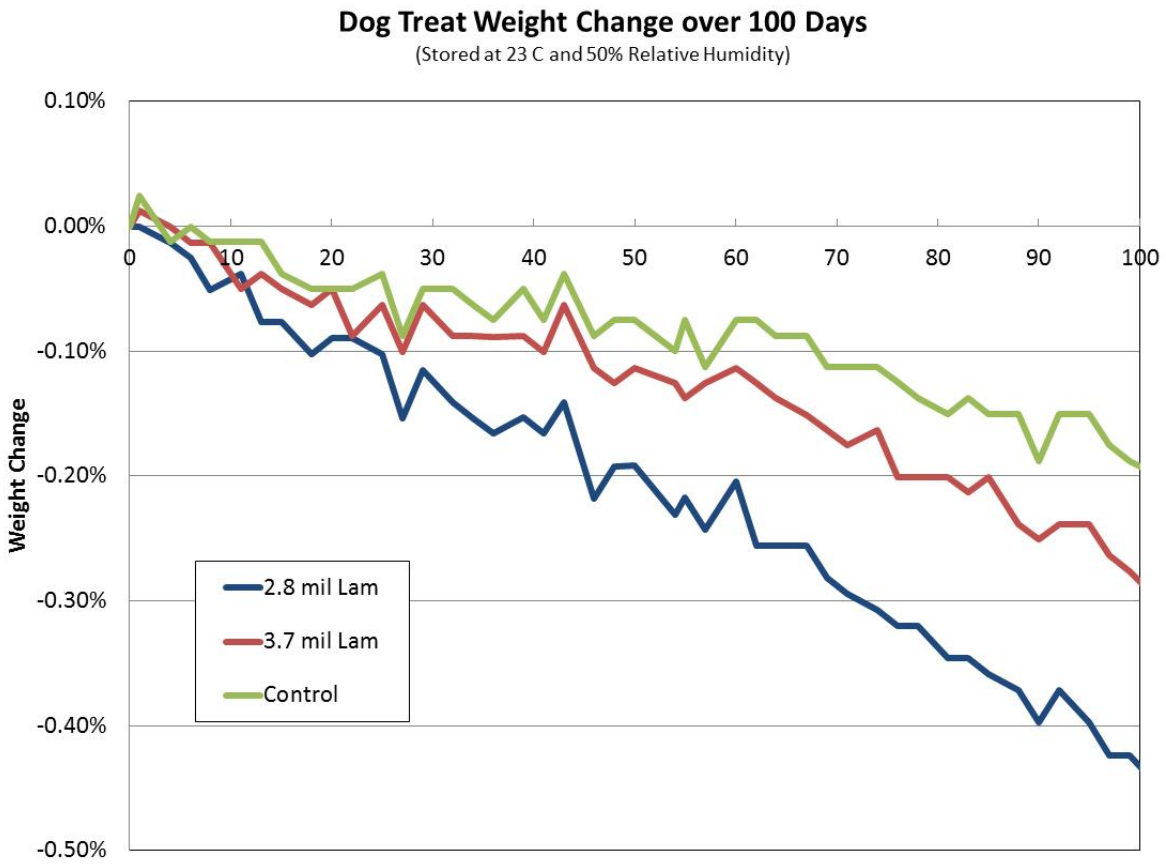
- **To assess potential real-world shelf-life performance, completed food-aging studies by making packages**
- **Cut 4-inch by 4-inch sections of film**
  - Produced control samples by using current packaging
- **Heat sealed film edges to fusion**
- **Filled package with food samples**
  - 25 to 28 grams of soup and dog treats
  - Film for packages weighed about 2 grams
  - 3 specimens per sample
- **Stored samples in 23oC, 50% relative humidity lab**
- **Weighed samples on Monday, Wednesday, and Friday for 100 days**

HDPE Barrier Lamination Comparison Testing
Food Aging (0.1% change ~ 0.025 gram change for 25-gram sample)



Weight Change After	50 Days	100 Days
2.8 mil Lam	0.01%	0.03%
3.7 mil Lam	0.02%	0.03%
Soup Control	0.02%	0.02%

HDPE Barrier Lamination Comparison Testing
Food Aging (0.1% change ~ 0.025 gram change for 25-gram sample)



Weight Change After	50 Days	100 Days
2.8 mil Lam	-0.19%	-0.48%
3.7 mil Lam	-0.13%	-0.30%
Dog Treat Control	-0.08%	-0.19%

HDPE Barrier Lamination Results Summary

2.8 mil Lam	Soup	Dog Treat
Tear	-	=
Haze	+++	+++
WVTR	+++	--
OTR	---	---
Food Aging	=	--

3.7 mil Lam	Soup	Dog Treat
Tear	=	+
Haze	+++	+++
WVTR	+++	-
OTR	---	---
Food Aging	=	-

+ indicates improved performance for lamination
- indicates better performance by existing structure

Conclusions

- **Significant improvement in WVTR for M6020SB may provide numerous options for new package designs**
  - Existing applications – cereal, cookie, cracker packaging
  - New applications
    - Clear and/or tough films with WVTR
    - Barrier lamination for metalized film replacement

- **Further structure enhancements may be possible through resin selection, blends, layer distributions, and gauge**

New HDPE Resins Offer Enhancements for New Packaging Films

Thank you for your attention.
Questions?

Steve Imfeld
stephen.imfeld@lyb.com

Tom Schwab
thomas.schwab@lyb.com

Lindsay Corcoran
lindsay.corcoran@lyb.com

Ryan Breese
ryan.breese@lyb.com

Disclaimer

All information ("Information") contained herein is provided without compensation and is intended to be general in nature. You should not rely on it in making any decision. LyondellBasell accepts no responsibility for results obtained by the application of this Information, and disclaims liability for all damages, including without limitation, direct, indirect, incidental, consequential, special, exemplary or punitive damages, alleged to have been caused by or in connection with the use of this Information. LyondellBasell disclaims all warranties, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose, that might arise in connection with this information.

This presentation includes industry data that we obtained from third party consultants. We have made no independent verification of, and we make no representations regarding, the accuracy of these data.

This presentation makes reference to certain non-GAAP financial measures, as defined in Regulation G of the U.S. Securities Exchange Act of 1934, as amended. We report our financial results in accordance with U.S. generally accepted accounting principles but believe that certain non-GAAP financial measures provide useful supplemental information to investors regarding the underlying business trends and performance of the company's ongoing operations and are useful for period-over-period comparisons of such operations. These non-GAAP financial measures should be considered as a supplement to, and not as a substitute for, or superior to, the financial measures prepared in accordance with GAAP.

This presentation contains time sensitive information that is accurate only as of the time hereof. Information contained in this presentation is unaudited and is subject to change. We undertake no obligation to update the information presented herein except to the extent required by law.

Before using a product sold by a company of the LyondellBasell family of companies, users should make their own independent determination that the product is suitable for the intended use and can be used safely and legally. SELLER MAKES NO WARRANTY; EXPRESS OR IMPLIED (INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY WARRANTY) OTHER THAN AS SEPARATELY AGREED TO BY THE PARTIES IN A CONTRACT.

LyondellBasell prohibits or restricts the use of its products in certain applications. For further information on restrictions or prohibitions of use, please contact a LyondellBasell representative.

Users should review the applicable Safety Data Sheet before handling the product.

Disclaimer

Before using a product sold by a company of the LyondellBasell family of companies, users should make their own independent determination that the product is suitable for the intended use and can be used safely and legally. SELLER MAKES NO WARRANTY; EXPRESS OR IMPLIED (INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY WARRANTY) OTHER THAN AS SEPARATELY AGREED TO BY THE PARTIES IN A CONTRACT.

LyondellBasell prohibits or restricts the use of its products in certain applications. For further information on restrictions or prohibitions of use, please contact a LyondellBasell representative.

Users should review the applicable Safety Data Sheet before handling the product.